Georgia Tech Sponsored Research

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Project	E-20-H41 G1685
Project director	Germanovich Leonid
Research unit	Civil Eng
Title	Fracture processes on small extraterrestrial bodies in the solar system
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Final Report for Period: 02/2002 - 01/2004
Submitted on: 06/21/2004
Principal Investigator: Germanovich, Leonid N.
Award ID: 0202058
Organization: GA Tech Res Corp - GIT
Title:
SGER: Fracture Processes on Small Extraterrestrial Bodies in the Solar System

Project Participants

Senior Personnel

Name: Germanovich, Leonid
Worked for more than 160 Hours: Yes
Contribution to Project:

Post-doc

Graduate Student

Name: Chanin, Chanin
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Sim, Youngjong
Worked for more than 160 Hours: No
Contribution to Project:

Undergraduate Student

Technician, Programmer

Other Participant

Research Experience for Undergraduates

Organizational Partners

Other Collaborators or Contacts

Prof. Arcady Dyskin, The University of Western Australia

Activities and Findings

Research and Education Activities:
RESEARCH ACTIVITIES:

Traditionally, asteroids and comets are considered to be an important source of information on the early Solar System. They pose a risk to life on Earth, but also represent a potential source of metals, other raw materials, and water in the near-Earth space. The defense against asteroids and comets has become a popular media and research topic. Geomechanical support of future landing missions is vital for the characterization of landing surface topography and design of the landing apparatus. The vast majority of data concerning asteroids and comets has been obtained via remote observations based on the assumed surface properties, which are functions of former and ongoing geomechanical processes. Yet, there has been no or hardly any quantification and mathematical treatment of the possible role of geomechanical processes in the evolution of asteroids and comets.

In this research, we incorporated principles of terrestrial geomechanics in the framework of mechanical processes that occur on asteroids and comets. Geomechanical processes on terrestrial planets (i.e., Mercury, Venus, Earth, Moon, and Mars) are significantly affected by such factors as gravitation, tectonics, volcanism, and erosion, which are considered absent or of no consequence on small extraterrestrial bodies. In essence, asteroids represent the simplest geomechanical systems (no air, no water, extremely low gravity, primitive rocks) and end-member case with respect to conventional (terrestrial) geomechanics.

Conference and Meeting Presentations:

American Geophysical Union Meeting, San Francisco, December 2001.

6th North American Rock Mechanics Symposium, Houston, TX, June 2004.

American Geophysical Union Meeting, San Francisco, December 2003.

Departments of Civil Engineering, Earth Sciences, and Physics, Purdue University, October 2003

Cambridge University, King's College, Cambridge, UK, May 2002

Schlumberger, Paris, France, December 2002

Department of Civil and Mineral Engineering, University of Minnesota, Minneapolis, November 2001

EDUCATIONAL ACTIVITIES:

Two Ph.D. dissertations (one completed) were partially supported by this grant (see the publication section). The results of this research are incorporated into both undergraduate and graduate level courses taught at Georgia Tech. In particular, courses CEE 6751 Physical Properties and Rheology of Rocks, CEE 6451 Rock Mechanics, and CEE 6482 Applied Fracture Mechanics bnefited from this research.

Findings:

As a result of analysis of multi-scale fracture processes occurring on asteroids, we proposed that thermal stresses induced by the 'seasonal' periodic heating due to the motion of the asteroid around the Sun in elliptical orbits coupled with short 'daily' rotations around the axis of inertia are primarily responsible for disintegration of asteroid material. This concept is appealing and seems to be rather robust because the asteroid temperature changes on various spatial and temporal scales and independently of other possible factors, such as tidal stresses, collisions, rotational spin-up, etc. Contrary to other mechanisms suggested in the recent literature, the magnitude of induced thermal stresses sufficiently exceeds the expected strength of the asteroid material.

The devised model also explains mechanics of the formation of the soil (regolith) on asteroids and how the soil formation changes the surface topography. It is generally believed that collisions with other heliocentric bodies represent the main mechanism of erosion on the asteroid surface. Because near-Earth asteroids have been undergoing a lengthy hiatus in impact cratering since they left the main asteroid belt, this concept implies that currently no fresh regolith is being produced on their surfaces. We suggested that contrary to this conventional concept, regolith/soil formation is an ongoing process caused by thermal space weathering, which is an effective means of erosion even in the airless, waterless, and low-gravity environment.

Although we also proposed a new model of cometary outbursts, due to the time limitation and unforeseen difficulties in modeling thermal processes on asteroids, this model has not been advanced in detail. Yet, we suspect that sublimation of cometary material caused by crystallization of the amorphous ice produces large hydraulic fractures. Propagation of these fractures transports pressurized vapor-dust emulsions to the surface of the comet nucleus resulting in catastrophic vapor-dust outbursts. The microscale physics of sublimation coupled with macroscale crack propagation determine linkage between the outburst rate, comet tail dimensions, and the expected nucleus life-time.

The developed concepts are consistent with the data on asteroid Eros and comet Halley obtained from close distances by NASA's NEAR-Shoemaker probe and ESA's spacecraft Giotto in 2000 and 1986, respectively.

Training and Development:

Ph.D. work of two graduate students, Mr. Chanin Ruangthaveekoon and Mr. Youngjong Sim, was partially supported from this project. In addition, they both served as Graduate Research Assistants for course CEE 6451 Rock Mechanics. This course incorporated results from his

Outreach Activities:

Three public lectures on the results obtained with the support from this grant were given at:

Cambridge University, King's College, Cambridge, UK, May 2002

Schlumberger, Paris, France, December 2002

Schlumberger, Sugar Land, Texas, July 2001

Journal Publications

Leonid Germanovich, Chanin Ruangthaveekoon, Arcady Dyskin, "Fracture processes on asteroid 433 Eros", Science, p. , vol. , ( ). in preparation, to be submited soon

Books or Other One-time Publications

Chanin Ruangthaveekoon, "Fracture processes on small extraterrestrial bodies in the solar system", (2004). Thesis, work in progress
Editor(s): Georgia Institute of Technology
Bibliography: In preparation

Youngjong Sim, "Mechanics of complex hydraulic fractures in the earth's crust", (2004). Thesis, Published
Editor(s): Georgia Institute of Technology
Bibliography: Georgia Tech Library

Web/Internet Site

URL(s):
http://www.ce.gatech.edu/~geosys/geomat/
Description:

Other Specific Products

Contributions

Contributions within Discipline:
This project contributed to establishing a new discipline: extraterrestrial geomechanics.

Contributions to Other Disciplines:
It was possible to consider some astronomical developments within the geomechanical framework.

Contributions to Human Resource Development:

Contributions to Resources for Research and Education:
We are providing our results on our web site for other researchers to use at: http://www.ce.gatech.edu/~geosys/geomat/
Contributions Beyond Science and Engineering:

Categories for which nothing is reported:

Organizational Partners
Any Product
Contributions: To Any Human Resource Development
Contributions: To Any Beyond Science and Engineering